Freeze-Drying of Foods:

Cost Projections

Marketing Research Report No. 639

Marketing Economics Division Economic Research Service
U. S. DEPARTMENT OF AGRICULTURE

PREFACE

This study, designed for food processors, may interest owners and managers of drying, canning, or freezing establishments contemplating freeze-drying. Also, the study may help counselors advise prospective investors in the relatively new freeze-drying industry. Technicians and employees of freeze-drying plants, research workers in the field of drying, and public administrators may find the study useful. Specific cost information may be especially interesting to cost accountants, economists, and managers of freeze-drying establishments.

Costs in this report are only those that reasonably would be incurred in freeze-dry processing. However, all costs involved in preserving food by this method are not included. Not accounted for are varying expenses of (1) research and development, (2) risk, (3) samples, (4) travel, (5) quality control other than that involved in freeze-dry processing, (6) freezing expenses including building and labor, (7) storage and warehousing other than temporary storage for frozen and dried foods during processing, (8) filling equipment and labor, (9) packaging equipment and labor, (10) development of markets, and (11) advertising and promotion.

No attempt is made to describe costs of actual plants now in operation. Plants discussed in this report are intended to be prototypes of future freeze-drying plants. They are considerably larger, except for the 4-ton model, than most plants in business today. However, future plants probably will become much larger as industry volumes increase.

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SUMMARY

Various freeze-dry processing costs are examined by studying the operations of four hypothetical but representative processing plants. The plants are classified according to their daily capacities for removing water from frozen foods -- 4, 8, 16, and 32 tons.

Major cost factors are size of plant, duration of the drying cycle, and continuity of operation. Other factors are kinds of food dried, wage rates, and utility rates.

Labor accounts for 31 percent of processing costs (excluding costs of raw materials and packaging) in the smallest freeze-drying operation. Equipment depreciation accounts for 27 percent. In large plants, depreciation is about 40 percent of costs.

Utility costs range from 18 to 21 percent of total freeze-drying expenses. Fixed expenses other than depreciation are 16 to 19 percent. Salaries of workers are 3 to 5 percent.

Economies of size are significant in freeze-drying. In processing chicken, for example, the 4-ton plant at full capacity has costs of 8 cents per pound of water removed. The 8-ton plant's costs average 6.7 cents; the 16-ton plant, 5.4 cents; and the 32-ton plant, 4.4 cents. These costs are for 8-hour drying cycles. Corresponding figures for a 12-hour drying cycle are 8.7, 7.4, 6.0, and 5.0 cents, respectively.

Length of operating season is important in determining processing costs. In the 8-ton plant operating 250 days per year, shrimp cost 6.1 cents per pound to process. For the same plant, operating only 100 days per year, they cost 10.8 cents.

Labor shifts worked per day also are important. If the plant is operated 3 labor shifts per day (on a 250-day year), shrimp cost 7.9 cents per pound to process. If the plant operates 2 shifts per day, shrimp processing costs are 10.2 cents per pound. In a 1-shift operation costs average 16.8 cents.

Wage rates are less important to costs than length of operating season or shifts per day. For example, using low wage rates, the 16-ton plant processes mushrooms at an average cost of 4.1 cents per pound of water removed. Using high wage rates, the average cost is 4.5 cents.

Lowest processing costs are attainable in large volume operations. A plant with capacity to remove at least 30 tons of water per day (equivalent of 33 to 55 tons of frozen input product per day) appears essential for costs to be relatively low. Lower costs are needed for this industry to be competitive with other food processing industries. To achieve minimum costs these large plants also need to operate steadily. Most plants would have to process a variety of foods to maintain this volume, and would probably operate in conjunction with an integrated processing system -- food preparation, freezing, packaging, warehousing, and storage.

On the basis of processing costs and other factors, estimates are made of the size of the freeze-drying industry in 1970.

Dollar volume (at the processing level) for freeze-dried products in 1970 is projected at about $250 million, compared with $5 million estimated for 1962. Poundage volume is forecast at about 250 million in 1970. This volume could be handled

by 15 to 20 plants the size of the 32-ton model. Over 100 plants the size of the 4-ton model would be needed.

It is expected that meats, seafoods, prepared mixes, vegetables, fruits, berries, and dairy products may account for large volumes of freeze-dried items. Foods with lesser volumes include instant beverages, juices, puddings, and other desserts. New products resulting from freeze-drying will add to expected volumes.

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FREEZE-DRYING OF FOODS: COST PROJECTIONS

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INTRODUCTION

The future growth of the freeze-drying industry depends largely on the absolute level of freeze-drying costs. It also depends on the cost of freeze-drying relative to costs of processing by alternative methods. Developed here are estimates of the industry's future. Also, predictions are made concerning competition of freeze-drying with other food processing industries, and the effects on associated industries.

Background

Freeze-drying has been fairly common for many years in the medical and drug industries. Techniques for so treating blood plasma were developed and used extensively during World War II. More recently, drying times were reduced so that a product could be dried in 20 hours or less. Lower costs resulted, and the drying method became of interest to the food processing industry.

Much early work in food freeze-drying was done in Denmark in the early 1940's. Basic work was continued at the Aberdeen, Scotland, Station. 1/ By 1957 the process appeared promising enough that several companies were in small-scale production and others had pilot plants. Ten U. S. companies are now in commercial production (October 1963). About 20 European companies are in production. 2/ With cycle times now reduced to 12, 10, or even 8 hours, we may expect lower costs and even greater interest among food processors. The 1962 estimate of production in the United States is about 5 million pounds, valued at about $ 5 million at the processing level.

Objectives

The general purpose of this study is to add to the economic understanding of freeze-drying. Presented are some research projections that serve as a basis for estimating the future of food freeze-drying, especially as processing costs affect the industry. Specific objectives include: (1) Determining the effect of different foods, multiple shifts, length of processing season, wage rates, and drying-cycle time on short-run, freeze-dry processing costs and (2) determining the effect of plant size on long-run costs. Emphasis is on changes in cost of freeze-drying associated with changes in size or scale of the plant.

1/ The Aberdeen Station was opened in 1951 and closed in 1961. Its work is reported in The Accelerated Freeze-Drying Method of Food Preservation. Her Majesty's Stationery Office, London, 1961.

2/ Bird, Kermit. A Directory of Freeze-Drying. U. S. Dept. Agr., Econ. Res. Serv., 1963.

What is Freeze-Drying?

Freeze-drying is a sublimation process that removes moisture from frozen products without appreciably changing the shape, color, or taste. Sublimation means that ice in the food goes directly from solid to vapor, bypassing the liquid phase.

This process takes place in a vacuum chamber at very low pressures (approximately 750 microns or less). Heat inputs are carefully controlled throughout the cycle. Cellular structure remains intact. Foods emerge sponge-like, and the resulting "voids" aid in rehydration. With water removed, the food may be stored for long periods without refrigeration. The dried food loses 50 to 90 percent of its weight; its final moisture content is 2 percent by weight. Reconstitution is accomplished by simply adding water or other liquids. The dried product has a high attraction for moisture and oxygen. It must be tightly packaged to keep these out. Careful packaging minimizes bacterial action and oxidative breakdown.

Ideally, only distilled water is removed from the product by freeze-drying, and oils and other carriers of flavor remain. Although many flavors do remain within the product, the water-soluble ones are sometimes removed. Thus, flavor loss is a problem. It is conceivable that extracted flavors might be advantageously recovered, as in other drying processes.

Theoretical Considerations

Technical aspects of freeze-drying are of concern in this paper only indirectly through their effect on costs. 3/ The theoretical framework used is one developed by other researchers for reports of a similar nature. 4/ The framework is based on modifications of the conventional production theory. Particular needs are suggested by examining how firms operate in closely associated food processing industries.

Source of Data

Visits were made to six freeze-dry equipment manufacturers in the United States and Canada. With cooperation of engineers in these companies, equipment needs were derived and investment and operating costs of various items of equipment calculated. Much utility usage data, especially power required, was obtained from these engineers. Specifications concerning condenser temperatures, evacuation methods, shelf-loading capacities, cabinet sizes, length of drying cycles, and basic materials-handling methods were outlined. Data supplied by these manufacturers were supplemented by other data from European firms.

Also surveyed were seven U. S. companies engaged in processing freeze-dried foods. Production men, engineers, management officials, and accountants assisted

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3/ One of the most complete books dealing with technical aspects of freeze-drying is Freeze-Drying of Foods, the proceedings of a conference in Chicago, April 12-14, 1961. This book contains an exhaustive identification of problems, and an exploration of possible solutions. Edited by Frank R. Fisher, National Academy of Sciences, National Research Council, Washington, D. C., 1962, 237 pages.

4/ The California Agricultural Experiment Station has issued a series of reports dealing with cost and efficiency. Notable is Economic Efficiency in Plant Operation with Special Reference to the Marketing of California Pears, French, B. C., Sammet, L. L., and Bressler, R. G., Vol. 24, No. 19, Hilgardia, July 1956. This report covers theoretical aspects of costs and efficiency research.

in estimating labor standards, suitable wage rates, building requirements, utility usage and rates, equipment costs of items not in the freeze-drying category, management costs, depreciation rates, repair allowances, and fringe benefits. Other information supplied by processors included tray-loading quantities, cycle times, space requirements, and product-handling procedures. Information concerning utility rates came from processors and utility companies.

All persons helping figure costs in the study understood that least-cost items of equipment, labor, utility rates, and methods were desired. Data on moisture percentages were derived from USDA sources. 5/

PROCEDURE

Model freeze-drying plants were constructed on paper. Model building, a common engineering technique, is used by architects and engineers. A similar method was used here. The first step in designing cost models was to estimate amounts and costs of various needed inputs. Then the size of plants to use as prototypes was determined: These were 4, 8, 16, and 32 tons of water evacuation ability per 24-hour day. For each of these capacity operations, building, equipment, labor, utilities, and management were combined to make these paper models approximate operating conditions.

A technique using models allows control of variables affecting efficiency. Construction of a model not only provides a basis for determining cause and effect relations, it also yields insights into underlying physical input and output relations. These, together with prices, determine average cost curves and other relevant cost functions.

Capacities in the model plants are at a level much higher than most plants actually in operation. The small 4-ton model is about the size of several larger actual plants. With the growth in size of plants now evolving in this industry, these four variations in plant size probably will typify the range of plant sizes in the future. Our largest model, with a capacity of about 40 to 50 tons of raw product per day, is similar to a canning or freezing operation that has minimum costs.

Construction of models may be summarized as follows:

(1) Development of economic-engineering models.

a. Ascertain physical inputs of labor, management, equipment, building, and utilities for the several stages of production. Determine limiting factors and capacities of models.

b. Define investment needed for equipment and plant. Find rates of depreciation, interest, maintenance, taxes, and insurance for investment items for each model.

c. Determine relations within a plant concerning product cycle lengths, labor shifts, and lengths of season for each model.

(2) Estimation of short-run cost functions.

5/ Agricultural Research Service. Nutritive Value of Foods. U. S. Dept. Agr., Home and Garden Bul. No. 72, Sept. 1960.

a. Determine fixed costs per year for various products and cycle lengths.

b. Determine variable costs for the several products, cycle lengths, length of season, and labor shifts.

c. Determine total costs per year. Calculate average cost curves when plants are run various ways.

(3) Determine long-run average cost function, or the "economies of size" curve from the series of short-run cost curves constructed for each model.

In developing average cost functions, a stipulation was that each model plant, unless otherwise mentioned, operated 250 days per annum. Where the season length is analyzed, a season of 100 to 350 days is used. In these instances total fixed costs do not vary on an annual basis, although they do on a per day of operation basis.

Freeze-drying costs were analyzed using 8-hour, 10-hour, and 12-hour drying cycles. Some freeze-dry processors are now using an 8-hour cycle, although many products are dried on a much longer cycle. The general trend has been toward shorter cycles which reduce costs.

The following four products are used to give a cross-section of the cost effect of moisture in the frozen input food: Chicken, beef, shrimp, and mushrooms with 56.0, 60.0, 70.4, and 90.0 percent moisture, respectively.

DESCRIPTION OF THE SYSTEM

Processing Techniques

The first step in freeze-drying is food preparation. Essential for cooked products, it is also important in uncooked foods. After preparation, food is quick-frozen. Temperature and time of this process depend on the individual product. Then the frozen food is placed on drying trays. The amount of food per tray depends on length of drying cycle, moisture of raw product, and loading methods used. Loaded trays are placed in a freeze-drying cabinet, and air is pumped from the cabinet. Reducing pressure to operating limits takes about 5 to 7 minutes. By the time the pressure has dropped below 4.5 mm. (mercury absolute), any melting has ceased. If melting has occurred the product refreezes.

Heat, applied between trays through heating plates or coils, raises them to an initial 300° F. Then temperatures are gradually reduced so temperature of the product does not exceed 140° F. Sublimation now takes place -- always below the eutectic temperature (lowest melting point) of the product. Heat causes the ice to sublime, and the resulting vapor flows from the cabinet to the condenser. The core of ice within the product disappears when the food is dried to about 2 to 4 percent moisture and the food is now freeze-dried. Heat is turned off and the cabinet is backflushed with nitrogen. The product is removed from the cabinet; it is now ready for packaging.

Most freeze-dried foods on the market are nitrogen or vacuum packed. Both cans and flexible pouches are used for packages. Cans, however, appear to have advantages; they offer better protection for the friable products and a satisfactory seal is more easily attained.

Water Evacuation

Vapor handling systems of the model plants are assumed to have sufficient capacity to attain and maintain a 1 mm (mercury, absolute) pressure. This helps assure good product quality at the maximum vapor flow. Rate of moisture flow is affected by moisture of the product to be dried, size of the food particles, initial load in the cabinet, heat applied, and pressure used. Since water removal is greatest during the early part of a drying cycle, maximum vapor flow imposed on the system is minimized by operating the group of cabinets on staggered cycles through the day. For example, if the 4-ton plant had 4 cabinets in operation on an 8-hour drying cycle, a cabinet would be loaded every 2 hours throughout a 24-hour day.

Water vapor may be removed from cabinets by: (1) Discharging water vapor directly to water condensers or the atmosphere using steam-ejector vacuum pumps (common in Europe where there are large quantities of cold water for use in the water condensers) or (2) condensing water into ice using mechanical vacuum pumps and refrigerated condensers. This method is common in the United States. The system in the cost models is a combination of methods (1) and (2). Steam jets, in combination with water condensers, are used for the first hour of each drying cycle and remove about one-third of the water from the cabinets. Later in the drying cycle the cabinet is switched to the mechanical pump and a refrigerated condenser system that maintains low pressures and removes the remaining two-thirds of the water vapor at a slower rate.

This combination system has several advantages. It has a slightly higher investment cost than a complete steam-jet system, but not as expensive as a complete mechanical pump system. It costs less to operate than a steam-jet system, but more than the mechanical pump system. Maintenance costs, high in a mechanical pump-refrigerated condenser system, are minimized by having the large vapor flow move through the steam system. In addition, an insurance factor is supplied: If one system breaks down, the other can maintain low pressure and prevent melting and subsequent food spoilage. In actual situations, a water evacuation method should be selected only after a plant site is chosen and local conditions are studied.

Freezing and Sublimation

Temperatures and times involved in quick-freezing depend upon the particular product being frozen. Freezing should be done at a rate to prevent cell rupture; the primary objective is to prevent development of large ice crystals that disrupt cells and membranes and change ionic concentrations. Supercooling while freezing should be avoided. Supercooling causes violent heat movements and changes in volume and concentration. During the period between quick-freezing and freeze-drying, food should be held at temperatures that prevent melting -- about 0° F. If freezing and frozen storage are handled correctly, a better freeze-dried product is produced.

Freeze-drying of food generally requires quick-freezing outside the system. An important exception is the vacuum-freezing process used in some plants for mushroom freeze-drying. Chilled to 35° F., mushrooms are placed in freeze-dry cabinets, and pressure is lowered. They freeze in this lower pressure. Heat is applied and the sublimation process begins. This technique discharges about 20 percent of the moisture previous to sublimation, and some physical product changes occur. Technically, we do not define this as freeze-drying, although for some foods the final product is similar to a true freeze-dried one.

Both radiant and conduction heat are used in model plants. 6/ Plates or tubing coils are heated by oil or water solution. They usually are anodized or painted black to attain maximum radiation. Suitable drying-cycle times and drying temperatures are assumed known and used, so food quality is maintained.

DESCRIPTION OF COST ELEMENTS

Costs of freeze-drying depend upon many factors: Material-handling methods, efficiency in design of equipment and plant, volume of product, labor shifts, quality of labor, wage rates, utility rates, combination of input factors, and capacity. Other factors include product bulk, moisture content of product, and temperature of cooling water.

Processing costs are divided into two groups, fixed and variable. Examples of fixed costs are interest on investment, depreciation, and management salaries. Examples of variable costs are utilities and labor. Some items may be both fixed and variable--maintenance of equipment and electricity.

Fixed Costs

Fixed costs pertain to those associated with equipment, building, and salaries. Equipment includes that actually used in freeze-drying and materials handling. Freeze-drying equipment includes cabinets, condensers, vacuum pumps, steam-ejector system, water tower, and controls. Equipment costs for each model were estimated using the investment cost per square foot of shelf area as a basis. For the 4-ton plant the cost is $150 per square foot (table 1). This includes installation and freight costs.

Similar costs were designated for each plant with three cycle lengths and four products. Products were assumed to be loaded into the cabinets with the following weights per square foot of shelf area:

Length of cycle	Chicken	Beef	Shrimp	Mushrooms
	Pounds	Pounds	Pounds	Pounds
12 hours	3.0	3.0	3.0	2.5
10 hours	2.75	2.75	2.75	2.25
8 hours	2.5	2.5	2.5	2.0

Equipment investment costs were $145 per square foot of shelf area for the 8-ton model. The 16-ton plant had costs of $130 and the 32-ton plant had costs of $115 per square foot.

Annual equipment costs were determined from the equipment investment. Depreciation, 14 percent, was calculated on the basis that the equipment would have a

6/ For a description and analysis of this heating method, see "The Accelerated Freeze-Drying Method of Food Preservation". Her Majesty's Stationery Office, London, 1961.

5-year life with a 30 percent salvage value. The annual interest rate on average investment was 6 percent (3 percent of initial investment). Insurance and taxes were 2 1/2 percent of the initial investment. Maintenance supplies were 1 percent. Depreciation, interest, insurance, taxes, and maintenance supplies totaled 20 1/2 percent of initial investment per year. Total and average equipment costs are shown in table 1.

The type and kind of other equipment used in these hypothetical model plants depend upon the size of plant. Included are forktrucks, conveyors, pallets, scales, scoops, work tables, and similar items.

Investment in other equipment ranges from $4,575 for the 4-ton plant to $9,000 for the 32-ton plant. Annual costs of these items are based on: Depreciation at 12 1/2 percent of initial costs, insurance and taxes of 3 percent, interest at 3 percent, and maintenace supplies of 1 percent. These total 19 1/2 percent. Annual costs of these items of other equipment are $824 for the smallest plant and $1,620 for the largest plant (table 2).

Building costs were based on square footage of floor space. The small plant needs 2,700 square feet and the largest plant 16,621 square feet. Cost per square foot is $16 for the smallest plant and $14 for the largest. Building cost includes land. Buildings of the 2 small plants have 16-foot to 18-foot ceilings. There are 22-foot ceilings in the 2 large model plants. Solid floors, good lights, air conditioning, heat, and plumbing with adequate water and sewerage facilities are provided. Refrigeration rooms, storage units, and office space are not included in the building cost estimates.

Annual costs of building and land are based upon 2.2 percent depreciation (assuming 45-year building life with no salvage value), insurance and taxes 4 percent, repairs 1 percent, and interest 3 percent. All are based upon initial investment figures. Yearly costs are $4,406 for the smallest plant and $23,735 for the largest (table 2).

Office rental cost is based upon square footage of space needed. Offices range in size from 120 square feet for the smallest model to 200 feet for the largest. Annual rental costs per square foot of floor space are $3.50 for all plants. Annual rental cost for the small plants is $420; the largest plant, $700.

Telephone and telegraph costs range from $600 per year for the smallest plant to $1,000 per year for the largest plant.

Office workers include a manager and one or more secretary-clerks. An important assumption is that the manager is employed by a company or firm of which the freeze-drying operation is but a part. Thus, his time and services are divided between the freeze-drying operation and other functions. This assumption of divisibility of time is important to costs. For example, the 4-ton plant utilizes only one-fifth of a manager's time and is charged a corresponding amount (charge is one-fifth of $10,000, plus fringe benefits). Annual costs for salaried employees are $6,840 for the smallest plant and $18,012 for the largest (table 3).

Total Fixed Costs

The 4-ton plant has annual fixed costs ranging from $60,000 to $75,000 (refer to appendix tables for details of fixed costs). Average fixed costs vary from 3 to 4 cents per pound of water removed, depending upon the product processed. The 8-ton plant

Table 1.--Freeze-dry equipment: Example of capacity, investment, and fixed costs of four model plants processing chicken 1/

Item	Unit	Plant size			
		4-ton	8-ton	16-ton	32-ton
Capacity:					
Water removed per day	Lb.	8,000	16,000	32,000	64,000
Frozen chicken per day	Lb.	14,815	29,630	59,259	118,518
Dried chicken per day	Lb.	6,815	13,630	27,259	54,418
Cabinets 2/	No.	4	8	16	32
Refrigeration 3/	Ton	60	78	150	290
Shelf area	Sq. ft.	2,000	4,000	8,000	16,000
Cost per square foot shelf area	Dol.	150	145	130	115
Investment in freeze-drying equipment	Dol.	4/300,000	580,000	1,040,000	1,840,000
Cost items:					
Depreciation 14%	Dol.	42,000	81,200	145,600	257,600
Interest 3%, insurance, taxes, 2½%, and maintenance supplies 1%	Dol.	19,500	37,700	67,600	119,600
Fixed equipment costs per year	Dol.	61,500	118,900	213,200	377,200
Fixed equipment costs per lb. water removed	Cent	3.1	3.0	2.7	2.4
Fixed equipment costs per lb. frozen chicken	Cent	1.7	1.6	1.4	1.3
Fixed equipment costs per lb. dried chicken	Cent	3.6	3.5	3.1	2.8

1/ Assumptions: Frozen cooked chicken is the only input product. It has 56 percent moisture and is dried to 2 percent. Three 8-hour drying cycles per day are used. Product is loaded on trays, 2.5 pounds per square foot of shelf area. Plant operates 24 hours per day, 250 days per year.

2/ Number of cabinets is calaculated from number of cycles and load per square foot. For example, if the 4-ton plant uses a 10-hour drying cycle, 5 cabinets are needed instead of 4.

3/ Refrigeration is used for freezing at 1.8 tons of refrigeration per 100 pounds of food per hour. In sublimation 10 tons of refrigeration are needed for each 100 pounds of food sublimated per hour. The 4-ton plant requires 73 tons of refrigeration if all water is evacuated by refrigerated condensers. However, since one-third of the water is evacuated through steam-jet pumps, the actual refrigeration need is 11.1 tons for freezing and 41.2 tons for sublimation. These total 52.3 tons, so the 4-ton plant with its 60 tons is about 15 percent overcapacity.

4/ Of this investment, refrigeration investment requirements may be calculated separately using a rule of thumb of $1,400 to $1,600 per ton of refrigeration. Investment in refrigeration is $84,000 to $96,000. This is for a Freon 12 system (Mention of a specific product in this report does not imply recommendation by the U.S. Department of Agriculture over other similar not mentioned products.) Condensers are $20,000 to $24,000. The rest of the investment is for vacuum pumps, piping, shelves, valves, heat exchangers, delivery, and installation.

Table 2.--Model freeze-drying plants: Capacities, equipment (other than freeze-dry), building, office rental, telephone, and telegraph 1/

Item	Unit	Plant size 4-ton	8-ton	16-ton	32-ton
Capacity:					
Water removed per day	Thou. lb.	8	16	32	64
Raw product per day	Thou. lb.	9-15	18-30	36-59	73-119
Dried product per day	Thou. lb.	1-7	2-14	4-28	8-55
Equipment (other than freeze-drying):					
Investment	Dol.	4,575	6,200	7,900	9,000
Annual cost (depreciation 12½%, insurance and taxes 3%, interest 3%, and maintenance supplies 1%)	Dol.	824	1,116	1,422	1,620
Building:					
Floor space	Sq. ft.	2,700	4,860	9,234	16,621
Cost per square foot	Dol.	16.00	15.00	14.50	14.00
Investment in building	Dol.	43,200	72,900	133,893	232,694
Annual cost (depreciation 2.2%, insurance and taxes 4%, fixed repairs 1%, and interest 3%)	Dol.	4,406	7,436	13,657	23,735
Office rental:					
Space	Sq. ft.	120	144	168	200
Annual cost at $3.50 per sq. ft.	Dol.	420	504	588	700
Telephone and telegraph	Dol.	600	750	900	1,000
Total annual fixed costs	Dol.	6,250	9,806	16,567	27,055

1/ Assumptions: 250-day year, building is heated, air-conditioned, and constructed to last 45 years. Rooms have 16-18 ft. ceilings in 4-ton and 8-ton plants and 22-ft. ceilings in 16-ton and 32-ton plants. Within specified ranges costs are applicable to all products.

has total fixed costs of $108,000 to $140,000 yearly. Average fixed costs for this model range from 2 1/2 to 3 1/2 cents per pound.

The 16-ton model has average fixed costs of about 2 1/2 cents per pound. Total fixed costs are $200,000 to $240,000 annually. The largest model has annual fixed costs ranging from $340,000 to $420,000. Average fixed costs per pound are 2 to 2 1/2 cents. All these costs are based on a 24-hour per day operation and a 250-day per year season.

Variable Costs

Variable costs include labor wages, labor fringe benefits, utilities, and equipment maintenance. All vary directly with changes in output. Most variable costs are geared to a day's operation and do not vary within a day. If a model plant operates less than a complete day, one day's variable costs are charged because of restrictions and institutions governing the uses of labor and utilities.

Table 3.--Salaried employees: Examples of synthesized crews, salaries, and costs for model plants 1/

Item	Unit	Plant size			
		4-ton	8-ton	16-ton	32-ton
Manager:					
Time spent on freeze-drying per year	Percent	20	25	33	50
Annual salary	Dollar	10,000	15,000	18,000	18,000
Secretary-clerks	Number	1	1	1	2/ 1½
Annual salary	Dollar	4,000	4,400	4,800	4,800
Salary expenses per year	Dollar	6,000	8,150	10,800	15,800
Fringe benefits (at 14% of salary) cost per year	Dollar	840	1,141	1,512	2,212
Total cost per year	Dollar	6,840	9,291	12,312	18,012

1/ Assumptions: Freeze-drying is part of a larger operation. Manager's time is divided between freeze-drying and other operations. A 250-day year is used. Within specified ranges costs are applicable to all products.

2/ Part time worker's salary is $4,000 per year.

Utilities include electricity, steam, nitrogen, water and sewerage, and heat and lights. Electricity cost is calculated from the tons of refrigeration needed to operate the refrigerated condensers. Rates are manfuacturing ones. In the small plant the rate is 1.5 cents per kw.-hr. The rate per kw.-hr. decreases for larger plants; rate for the 32-ton plant is 1.0 cent per kw.-hr. Daily costs of electricity are $52.80 for the smallest plant and $198.40 for the largest.

Steam is assumed available with no investment in boilers. 7/ However, heat exchangers are included as part of the heating equipment. Steam rates among plants are constant (80 cents per 1,000 pounds) and do not vary with volume of steam purchased. The smallest plant uses 2.5 pounds of steam per pound of water, the largest plant needs 2.2 pounds. This includes steam used in defrosting the refrigerated condensers. Most steam is used to operate this steam-jet system, which is in operation during the first hour of each cabinet's drying cycle. During this 1-hour period about one-third of the water vapor is removed; then the steam-evacuating pumps are connected to a newly-loaded cabinet. During the remainder of the cycle, mechanical pumps maintain low pressures and evacuate the rest of the water. The smallest plant uses 40,000 pounds of steam per day through its jets and removes about 27,000

7/ Although steam boilers and other items for producing steam are not budgeted, it is estimated that annual steam costs would be approximately the same if steam were purchased.

pounds of water. Daily steam cost is $48.00 for the smallest plant and $369 for the largest (table 4). 8/

Nitrogen costs are based upon number of cabinet flushings. Rate for small-volume users is 0.9 cent per cubic foot and 0.5 cent for large-volume users. Daily cost of nitrogen is $32.00 for the small plant and $160.00 for the large one (table 4).

Water and sewerage costs are based upon volume of food processed. The smallest model uses 6 gallons of water and sewerage service per pound of water removed. The largest plant uses 3 gallons.

Costs of water and sewerage services are $1.00 per day for the smallest plant and $2.50 per day for the largest (table 4). Water used in cooling the water condensers of the steam-evacuating system is circulated through cooling towers.

Space heating and lighting costs are $1.00 per day for the smallest plant and $4.00 for the largest (table 4).

Total utilities are $135 per day for the smallest plant and $734 for the largest. Average utility costs are 1.7 cents per pound of water evacuated for the smallest plant and 1.1 cents for the largest. These costs pertain to a plant processing chicken and differ for other products. See appendix.

Labor, for identification, is separated into two groups of direct and indirect workers. Direct workers include persons handling the product--operator, assistant operator, product weighers, tray men, janitors, and quality-control workers. Indirect workers include those not handling product--department foremen, maintenance men, janitors, and quality-control technicians.

For each model plant, required hours of labor are estimated for each product and each handling method. Table 5 shows labor requirements and costs, using chicken as an example.

Each model plant is charged for the use of an operator on duty 24 hours per day. At $2.06 per hour, the daily expense is $49.44 and is the same for all four plants. An assistant operator is assigned each plant, at $1.73 per hour. Daily costs range from $20.76 for the smallest plant to $41.52 for the largest. Hours and rates per hour are computed and extended for every job in each plant.

Fringe benefits, estimated at 14 percent of wages and salaries, include Social Security payments of the employer, unemployment insurance, retirement, contributions, and other indirect payments of the employer. There are sufficient workers to do the necessary work even though vacations are taken, also coffee breaks, dress and undress

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8/ If efficiency were 100 percent steam used for heat of sublimation would be about 1,200-1,300 B.t.u.'s per pound of water extracted. Actually, steam usage is about 2,000 B.t.u.'s per pound of water extracted. This is only for heating the plates in the cabinets, and is about 2 pounds of steam for each pound of water evacuated.

In operating the steam-jet pumps it takes about 15 pounds of steam for each pound of water evacuated through these pumps. About one-third of the water is evacuated through the steam-jet system, so steam usage per day through the steam-jet system equals 15 times one-third of the water evacuated per day. In this system, evacuated water is condensed in cold-water condensers, which considerably lower steam consumption. Without the condensers, steam usage may go as high as 50 or 60 pounds of steam per pound of water evacuated.

Table 4.--Utilities: Examples of needs, usage, rates, and cost for model freeze-drying plants processing chicken

Item	Unit	Plant size			
		4-ton	8-ton	16-ton	32-ton
Capacity:					
Water usage per day	Lb.	8,000	16,000	32,000	64,000
Frozen chicken per day	Lb.	14,815	29,630	59,260	118,518
Dried chicken per day	Lb.	6,815	13,630	27,260	54,518
Steam: 1/					
Use per pound of water sublimated	Lb.	2.5	2.4	2.3	2.2
Use in sublimation	Lb.	20,000	38,400	73,600	140,800
Use in water evacuation at 15 pounds of steam per pound of water evacuated through the steam-jet evacuation system	Lb.	40,000	80,000	160,000	320,000
Total per day	Lb.	60,000	118,400	233,600	460,800
Cost per day at 80 cents per 1,000 lbs. 2/	Dol.	48.00	94.72	186.88	368.64
Electricity: 3/					
Refrigeration needed	Ton	60	78	150	290
Electricity per lb. water removed	Kw.-hr.	.44	.40	.35	.31
Use per day	Kw.-hr.	3,520	6,400	11,200	19,840
Cost per kw.-hr. 2/	Cent	1.5	1.3	1.1	1.0
Cost per day	Dol.	52.80	83.20	123.20	198.40
Nitrogen: 4/					
Use (33.3 cubic ft/ flushing/ cabinet)	Cu. ft.	4,000	8,000	16,000	32,000
Cost per day	Dol.	32.00	56.00	96.00	160.00
Water and sewerage:					
Water consumed per pound of water removed in drying	Gal.	6	5	4	3
Water consumed per day	Gal.	48,000	80,000	128,000	192,000
Water and sewerage per 1,000 gal 2/	Cent	2.0	1.8	1.5	1.3
Water and sewerage per day	Dol.	0.96	1.44	1.92	2.50
Cost of heat and lights for buildings per day	Dol.	1.00	1.75	3.00	4.00
Total daily utility costs	Dol.	134.76	237.11	411.00	733.54
Per pound of water removed	Cent	1.7	1.5	1.3	1.1
Per pound of frozen chicken	Cent	0.9	0.8	0.7	0.6
Per pound of dried chicken	Cent	2.0	1.7	1.5	1.3

1/ Usage depends upon time steam-jet evacuation pumps are used. It is assumed they will be used about 1 hour of each cycle, and take out about one-third of the water to be evacuated. Cabinets are staggered; no two are operated on the steam-jet pumps at the same time.

2/ Although this rate is used, individual firms may pay higher or lower rates.

3/ A water evacuation system using only mechanical pumps and condensers would need more refrigeration capacity and would have higher electricity usage than shown, but would consume less steam and less water.

4/ Figures pertain to a 3-cycle plant only. Cost of nitrogen: 0 to 2,999 cu. ft. used/day=$.009/cu. ft., 3,000-5,999=$.008/cu. ft., 6,000-11,999=$.007/cu. ft., 12,000-23,999=$.006, and 24,000 cu. ft./day and over=$.005/cu. ft.

Table 5.--Labor Force: Example of crew size, wages, and costs for model freeze-drying plants processing chicken 1/

Item	Unit	Plant size			
		4-ton	8-ton	16-ton	32-ton
Capacity:					
Water usage per day	Lb.	8,000	16,000	32,000	64,000
Frozen chicken per day	Lb.	14,815	29,630	59,259	118,518
Dried chicken per day	Lb.	6,815	13,630	27,259	54,518
Direct labor:					
Operator hrs./day	Hour	24	24	24	24
Cost/day @ $2.06 per hr	Dol.	49.44	49.44	49.44	49.44
Assistant operator hrs./day	Hour	12	16	24	24
Cost/day @ $1.73 per hr	Dol.	20.76	27.68	41.52	41.52
Produce weighers hrs./day	Hour	16	30	36	48
Cost/day @ $1.68 per hr	Dol.	26.88	50.40	60.48	80.64
Tray men hrs./day	Hour	8	8	9	10
Cost/day @ $1.68 per hr	Dol.	13.44	13.44	15.12	16.80
Tray washers hrs./day	Hour	8	16	24	30
Cost/day @ $1.68 per hr	Dol.	13.44	26.88	40.32	50.40
Indirect labor:					
Department foreman hrs./day	Hour	6	8	10	12
Cost/day @ $3.96 per hr	Dol.	23.76	31.68	39.60	47.52
Maintenance man hrs./day	Hour	8	10	12	16
Cost/day @ $2.20 per hr	Dol.	17.60	22.00	26.40	35.20
Janitor and cleanup hrs./day	Hour	3	3	4	5
Cost/day @ $1.63 per hr	Dol.	4.89	4.89	6.52	8.15
Quality control:					
Hours per day	Hour	2.4	2.7	3	4
Cost per day @ $1.77/hr	Dol.	4.25	4.78	5.31	7.08
Totals:					
Hours per day	Hour	87.4	117.7	146	173
Salaries per day	Dol.	174.46	231.19	284.71	336.75
Fringe benefits @ 14% of salaries	Dol.	24.42	32.37	39.86	47.14
Labor cost per day	Dol.	198.88	263.56	324.57	383.89
Labor cost per pound of water removed	Cent	2.5	1.6	1.0	0.6
Labor cost per lb. of input product (chicken)	Cent	1.3	0.9	0.5	0.3
Labor cost per lb. of dried chicken	Cent	2.9	1.9	1.2	0.7

1/ Assumptions: Figures pertain to a 250-day year, labor requirements for processing chicken, wage rates similar to those in a middle-size Midwest city.

time, and lunch periods. Fringe benefits are $24.42 per day for the smallest plant and $47.14 per day for the largest.

Large plants need less labor per pound of product handled than small plants. This is because of more automation and improved labor utilization. In instances where labor works beyond the stated capacity of the plant, labor is paid time and a half. Usual fringe benefits are added for overtime work. The small plant has average costs of 2.5 cents per pound of water and the large one 0.6 cent per pound of water removed.

Equipment maintenace is \$6.00 per day for the small plant and \$37.00 per day for the large plant. These figures are for labor only, and do not include repair parts, which are covered in another section.

Total variable costs range from \$340 per day for the small plant processing chicken to \$1,154 per day for the large plant processing chicken. See appendix tables. Variable costs per pound of water removed are 4.2 cents for the small plant and 1.8 cents for the large. Variable costs per pound of input product (assuming the product is cooked chicken) are 2.3 cents and 1.0 cent, respectively, for the small and large plants.

The 4-Ton Plant, an Example of Cost Design

The smallest plant is described in some detail to illustrate the method in handling costs of all the model plants. Operating 24 hours per day, it has a capacity of removing 4 tons of water per day. If cooked chicken is the product, the incoming weight is 14,815 pounds per day, and dried is 6,815 pounds. The frozen chicken has 56 percent moisture and is dried to 2 percent. It is processed in dices one-fourth and three-eighth inches in size in normal dark and white proportions. An 8-hour drying cycle is employed. Two and one-half pounds of frozen chicken are loaded per square foot of cabinet shelf area, and four 500-square foot cabinets handle this volume. Other freeze-drying equipment includes a heat exchanger, condensers, mechanical vacuum pumps, and a partial steam-ejector system. It is equipped with cooling tower. The 4 drying cabinets are loaded 2 hours apart, so the load on the vapor-handling system and labor are reasonably constant. Maximum temperature in the cabinets is 300° F. Refrigerated condenser temperature is minus 40° F. Sixty tons of refrigeration are available to freeze the product and cool the refrigerated condensers. Usual materials-handling equipment are available including scales, tray washer, fork trucks, and other necessary equipment.

The plant is supplied with: An operator on duty full time and an assistant operator who works 12 hours. These men are assisted by 16 hours of product-weighing labor, 8 hours of tray-washing labor, and 8 hours of tray-loading help. A foreman is in and out of the department and the freeze-drying process is charged with 6 hours per day of foreman time. Maintenance labor is 8 hours. Janitor and cleanup labor is 3 hours per day, and quality-control 2.4 hours per day. The manager devotes 20 percent of his time to this freeze-drying operation. One full-time secretary-clerk is designated.

Figure 1 shows a breakdown of the \$160,000 annual processing expenses of the plant. Labor is about 31 percent of total expenses. Depreciation is 27 percent, utilities are 21, and other fixed expenses of equipment and building are 16. Salaries are 4 percent and repairs are 1.

See tables 6, 7, 8, and 9 in the appendix for capacity and cost details of each model plant.

ANALYSIS OF COSTS

Before analyzing costs of freeze-drying, we review several assumptions affecting the methods of handling cost estimates:

1. Each model plant is an integrated department within a company or firm.

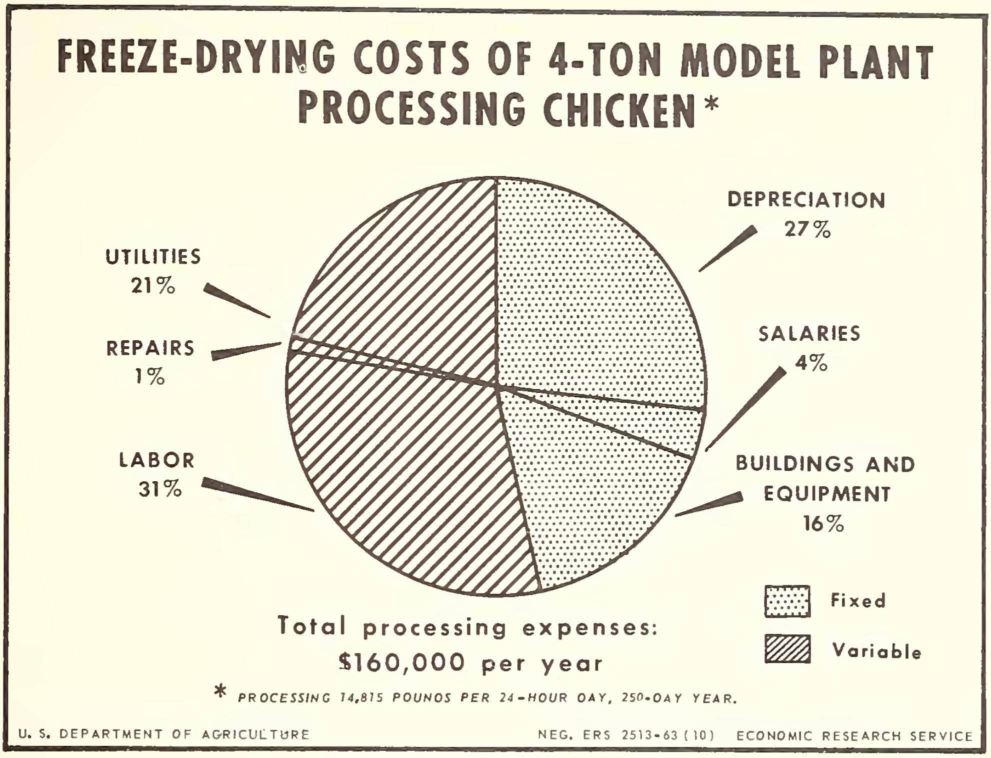

Figure 1

This allows all labor inputs to be classed as variable costs. For example, if a job requires 6 hours labor per day, it may be spread over 3 labor shifts in components of 2 hours each. Since our freeze-drying department is charged for only 6 hours, cost estimates are minimized. This assumption is particularly useful in calculating requirements for small plants where problems of labor divisibility are most bothersome.

2. Utility inputs are purchased rather than manufactured. Steam and other utilities are assumed bought from an outside source or the parent company. Since plants have no investment in boilers, this assumption has the effect of overstressing variable costs relative to fixed costs. However, if our utility rates are estimated correctly, total and average costs should be at the right level or the same as if the equipment for producing these utilities were owned by the freeze-dry department.

3. In the usual theoretical treatment, rates of increases of variable costs for a given scale depend on volume. Here, however, charges for some inputs are held constant for a given plant, within its range of operation. As an example, the electricity rate for the 16-ton plant is 1 cent per kw.-hr. This figure is based upon a 250-day usage year. If this plant were run at half capacity, it would still use the 1-cent rate, even though using half as much electricity. The 8-ton plant at full capacity would have equal usage, but would be charged more (1.3 cents per kw.-hr.). This rate equality within the operating range of a plant is justified on the basis of charging for expected rather than actual usage. In the case cited above, the 16-ton plant was designed for and expected to operate 250 days per year, not the 125 days.

Charging inputs strictly on the basis of volume usage is done for nitrogen, where rates per cubic foot are based upon volume purchased per month.

Long-Run Costs

Long-run costs are those fixed in the short run, but free to vary in the long run. Figure 2 shows short-run cost curves for the model plants. These curves show average costs per pound of water removed if plants operate at full capacity and also at several levels less than full capacity. If there were an infinite number of various-sized firms, each with a short-run curve, these curves would fit into the framework outlined by the model plants.

The long-run curve is drawn at the low points (capacity levels) of the short-run curves in an envelope fashion. This long-run (industry) curve has no upward turn at large volumes. Within the limits of this analysis, we deduce that further cost economies are possible with greater capacity operations.

Short-run curves in figure 2 show lowest costs are obtained by operating a plant at full capacity. Although further volume increases are possible, they are only attainable by operating more than 250 days per year and paying overtime wages. It will be shown later that this is a method which lowers rather than raises average costs.

Low processing costs at full capacity are illustrated in several instances where costs for several model plants at identical volumes may be compared. For example,

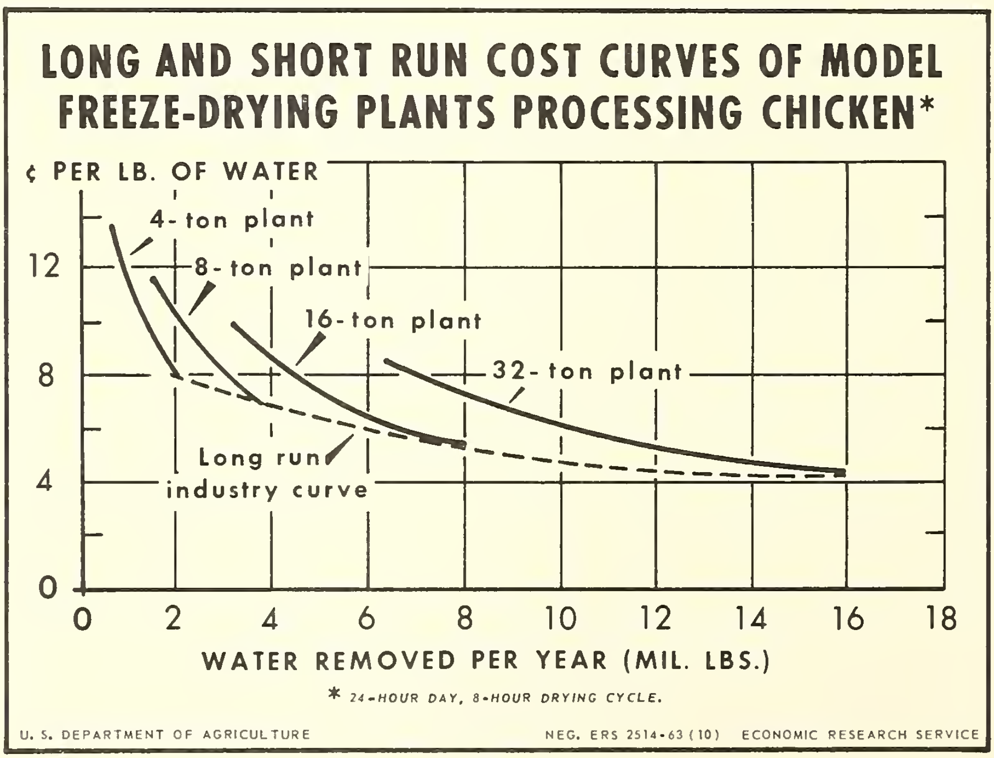

Figure 2

if we wanted to extract 4 million pounds of water from chicken in a freeze-drying operation, we could use a plant designed to extract this amount of water at its capacity level. This would be the 8-ton model. Or, a plant double this capacity (the 16-ton plant) could be run at half volume. In this comparison, the smaller plant has average costs of 6.7 cents per pound of water while the large plant shows costs of 8.3 cents. Processing costs are obviously lower for the small plant run at full capacity.

The long-run industry curve is the lowest-cost curve for all volumes of freeze-drying operations. This information is useful for industry planning. Suppose there is a need for freeze-drying about 30 million pounds of chicken. If this were done in one plant, having a capacity of 30 million pounds of chicken per year, average costs would be 4.4 cents per pound of water removed. Total yearly processing costs would be $704,000. Two plants half this size handling the same amount of chicken would have costs of 5.4 cents per pound or $864,000 per year. Four plants of one-fourth this capacity would show average costs of 6.7 cents per pound, or $1,072,000 per year. Eight plants equally handling the chicken at full capacity would have costs of 8.0 cents per pound or $1.3 million total costs per year. Total costs for the eight small plants are almost twice as much as for one large plant. Clearly, there are economies of size in this industry.

Short-Run Costs

Factors affecting short-run costs include: Products being dried, shifts per day, days per year, length of drying cycle, wage rates, and utility rates.

Statements concerning minimum cost levels do not imply that maximum profits are attained by operating a plant at lowest-cost points. Profits were not estimated in this report.

Length of season, as in most food processing industries, is important. Figure 3 illustrates costs of freeze-drying shrimp in an 8-ton model plant. Operated 250 days per year, costs are 6.1 cents per pound of water removed, or 4.2 cents per pound of shrimp processed. If operated 200 days per year, costs are about 6.9 cents per pound of water removed. At 100 days per year, costs are 10.8 cents. Also shown are costs of operating this plant longer than a 250-day season. It is assumed overtime is paid for every day worked more than 250 per year. Costs per pound of water removed are 5.5 cents at 300 days per year and 5.0 cents at 350 days. Thus, even though overtime wages are paid, costs decline as the length of processing season grows longer.

Costs associated with length of season differ for the various-size plants. Where a large proportion of costs are fixed it is important that the operation be run as continuously as possible. Figure 4 shows percentage of total costs that are fixed, with each of the four model plants operating at two levels of capacity. In the 4-ton model, 69 percent of costs are fixed if the plant runs 100 days per year; 47 percent of the costs are fixed if it operates 250 days. Larger, more completely mechanized plants have a high proportion of their costs fixed. The 32-ton plant has 78 percent of its costs fixed when run only 100 days per year. If run 250 days per year, 59 percent of its costs are fixed.

Food processed or dried is another variable affecting processing costs. Figure 5 shows that as the percentage of water in the product increases, costs per pound of input product increase. However, costs per pound of water removed decrease as the percentage of water increases. Total costs remain the same in the two instances,

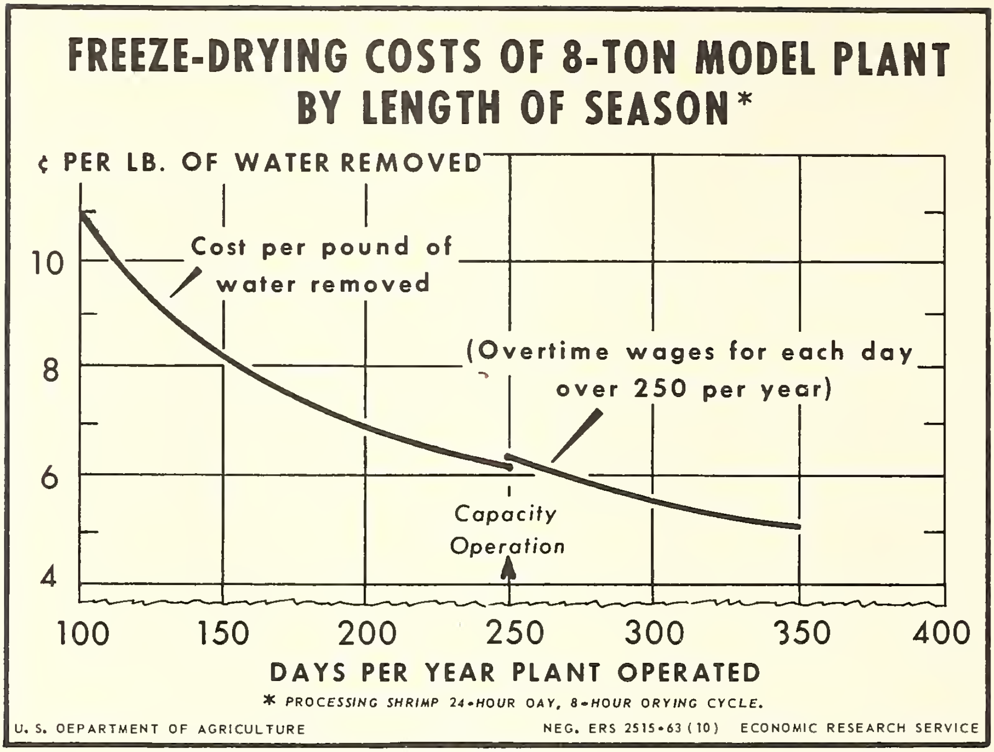

Figure 3

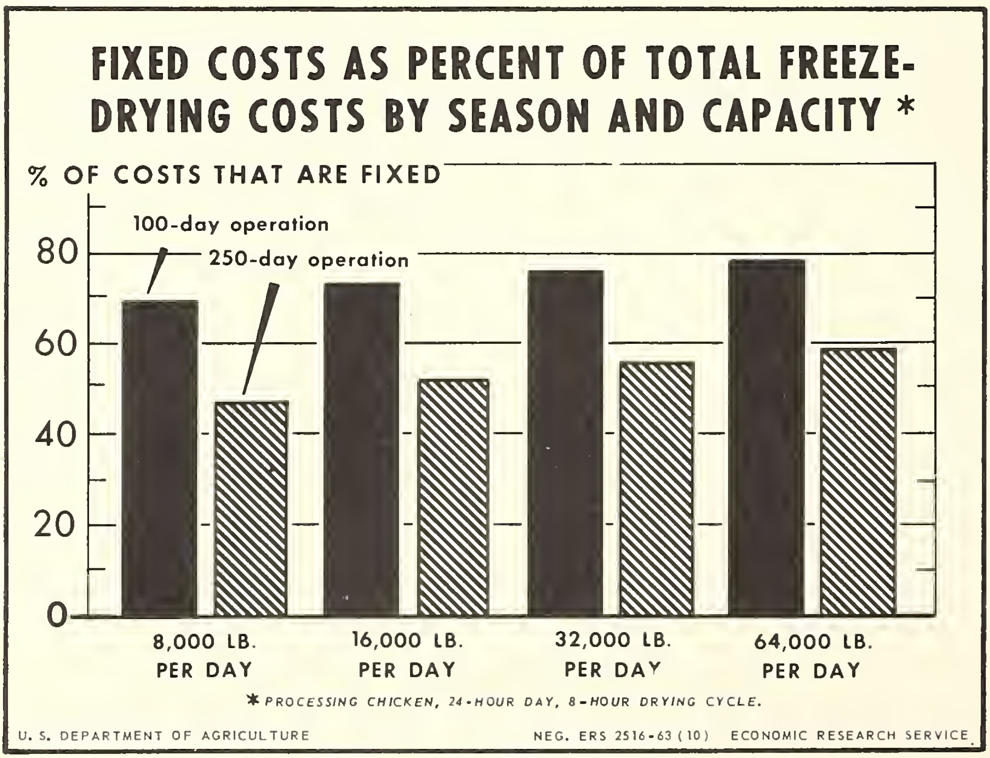

Figure 4

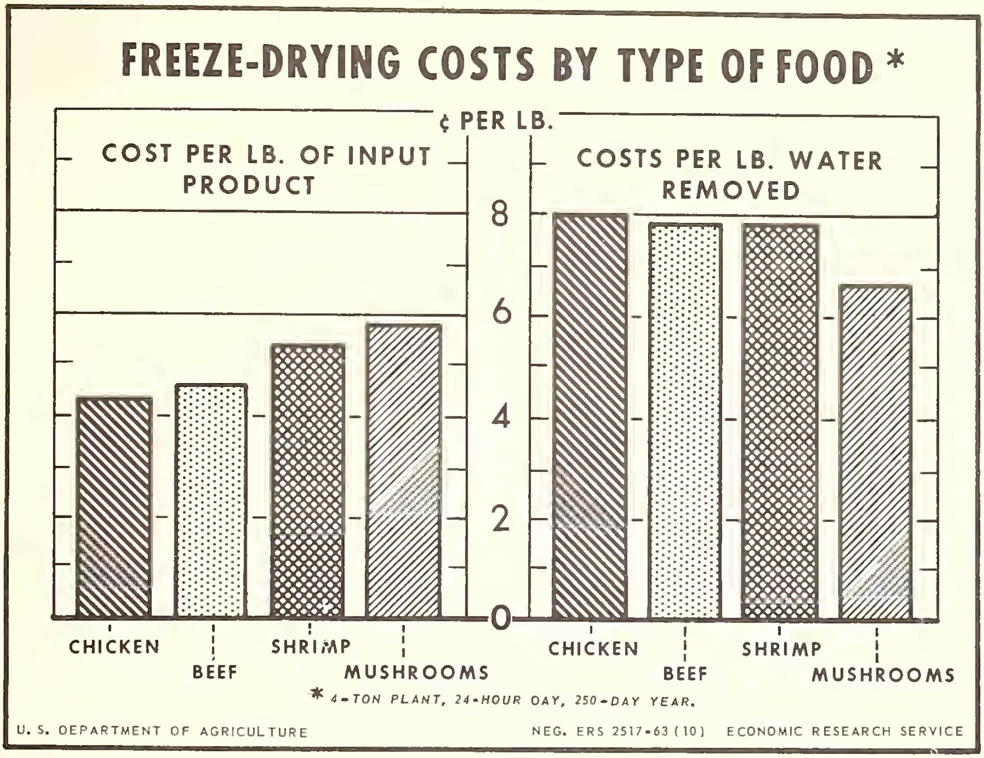

Figure 5

but in calculating average costs per pound of water we use a smaller denominator, resulting in higher costs per pound of water. As examples, we include mushrooms with 90.0 percent moisture, shrimp with 70.4 percent, beef with 60.0 percent, and chicken with 56.0 percent.

Chicken processing costs in figure 5 are 4.3 cents per pound of frozen chicken, while shrimp with 70.4 percent moisture are 5.4 cents per pound of frozen shrimp.

Bulkiness also affects drying costs. For example, 2 1/2 pounds of chicken, beef, or shrimp are loaded per square foot. Because of bulk, mushroom costs are higher than other products handled in a similar manner. In the model plants mushroom cabinets are not nitrogen backflushed and actual mushroom processing costs are lower than might be indicated.

Larger plants have lower costs than those shown. For example, cost of mushrooms in the largest plant is 3.9 cents per pound of input product compared with 5.8 cents in the small model plant.

Labor shifts per day show how number of hours a plant is operated affects plant processing costs. Illustrated in figure 6 are costs associated with 24-hour, 16-hour, and 8-hour operations. It is assumed no overtime wages are paid, a full labor shift is available to work, there are few institutional restrictions such as unions, and the plant runs 250 days per year.

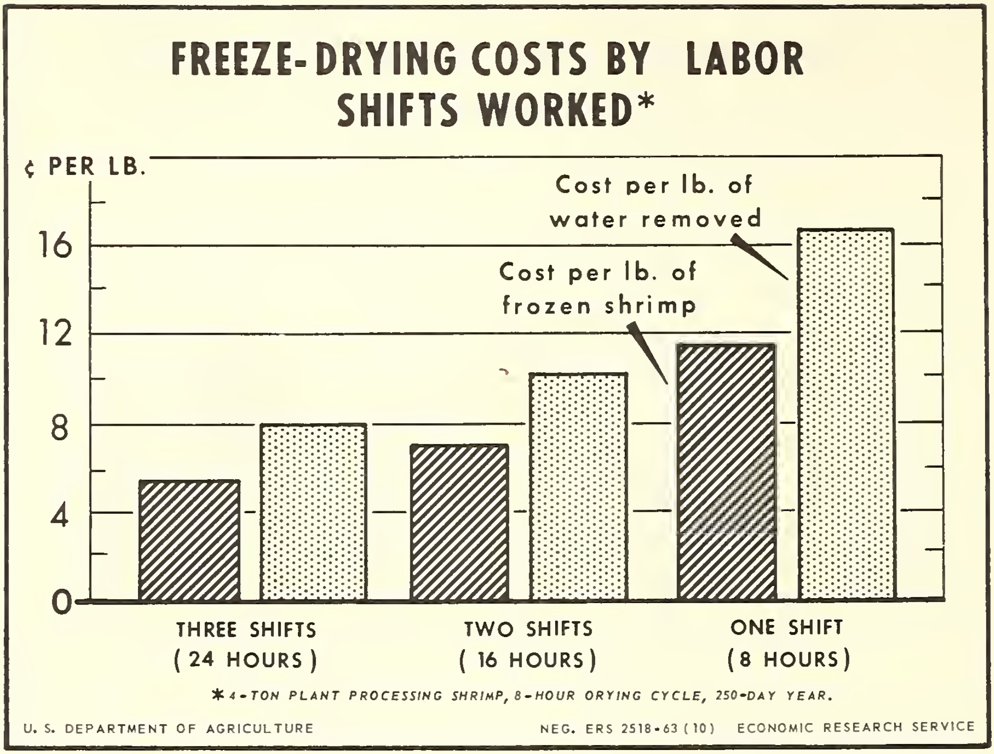

Figure 6

If the smallest model plant operates 24 hours per day, cost per pound of water removed is 7.9 cents. At 16 hours per day, cost is 10.2 cents; and 8 hours per day, 16.8 cents. Costs per pound of product show a similar relation. Frozen shrimp on a 24-hour day cost 5.4 cents; they are 7.0 cents if the plant operates 16 hours per day; on an 8-hour day, 11.5 cents.

Costs are halved as a plant is able to change from an 8-hour to a 24-hour operation. This cost advantage of operating a plant many hours per day, although applying to any food processing industry, is particularly important to freeze-drying with its high ratio of fixed costs. Fixed costs do not increase as volume expands, and as a consequence larger volumes are important in reducing average costs.

Length of drying cycle has been an important factor in making freeze-drying of food economically feasible. Drying cycles of 24 to 30 hours were not uncommon in the past. With advanced technology in food freeze-drying (for example, newer heat methods, lower pressures, and higher temperatures) cycles in the range of 8 to 12 hours are now commonly used. A drying cycle includes the time required to load cabinets, dry the food, unload, and clean the equipment. Actual drying may be as short as 6 hours in an 8-hour cycle. To some extent the length of the cycle is related to quality -- longer cycles with lower temperatures generally produce higher quality foods.

To show how cycle times affect processing costs, 12-hour, 10-hour, and 8-hour cycles are illustrated using chicken and mushrooms as products (fig. 7). Freeze-drying costs for chicken average 6.0 cents per pound using a 12-hour drying cycle,

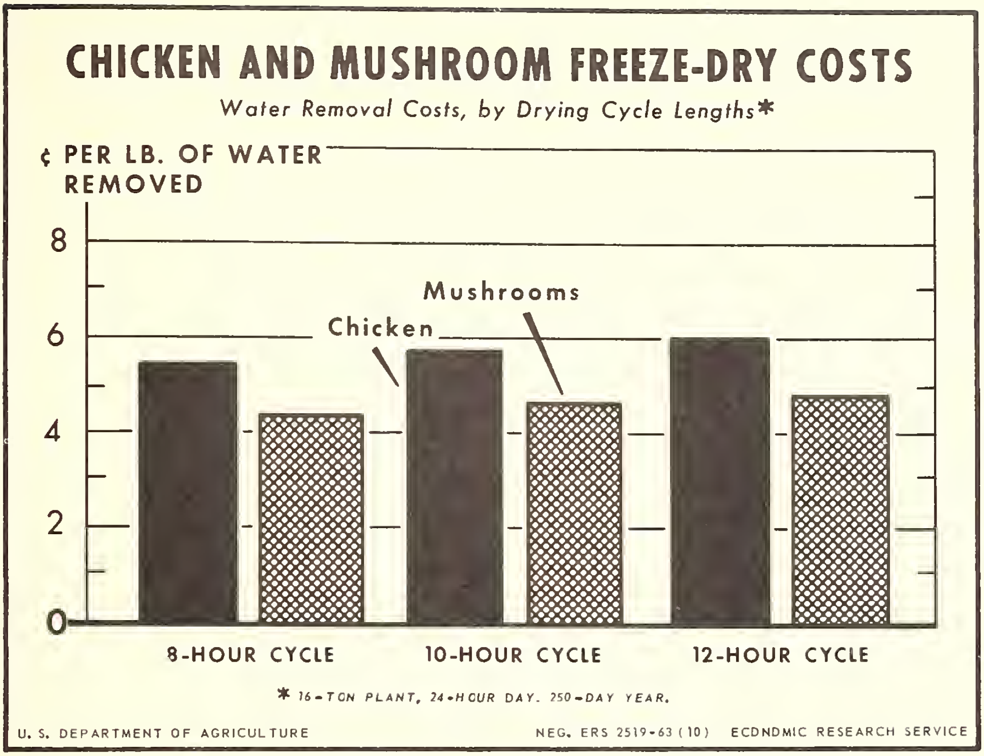

Figure 7

5.7 cents using a 10-hour cycle, and 5.4 cents for an 8-hour cycle. Average processing costs are 10 percent less for an 8-hour cycle than for a 12-hour cycle.

Mushrooms show a similar relationship. Average costs per pound of water removed are 4.8, 4.6, and 4.3 cents, respectively for the 12-hour, 10-hour, and 8-hour cycles (fig. 7).

Wage and utility rates in the analysis have been typical of a medium-sized Midwestern city, such as Omaha, Nebr. 9/ To show the effect of different rates on freeze-dry processing costs, two contrasting wage-level areas are compared. Wage rates in the South and certain other areas of the country are about 15 percent lower, and salaries are about 11 percent lower than those estimated for Nebraska. The West Coast and certain other areas of the country have wage and salary rates 25 percent higher than in Nebraska. Figure 8 shows wage levels affecting average costs. In this comparison the 16-ton model plant processing muchrooms was used. Average freeze-drying costs using Omaha wages were 4.3 cents per pound of water removed. Using West Coast wages, average costs were 4.5 cents. Using Southern wages, average costs were 4.1 cents. Labor costs, about one-third of total costs, have a substantial effect on average drying costs. If wage rates are correctly estimated, high wage rate areas have processing costs about 10 percent higher than the low wage rate areas. This assumes equal labor productivity.

9/ Wages refer to money paid to hourly workers. Salaries refer to monetary benefits accruing to monthly employees.

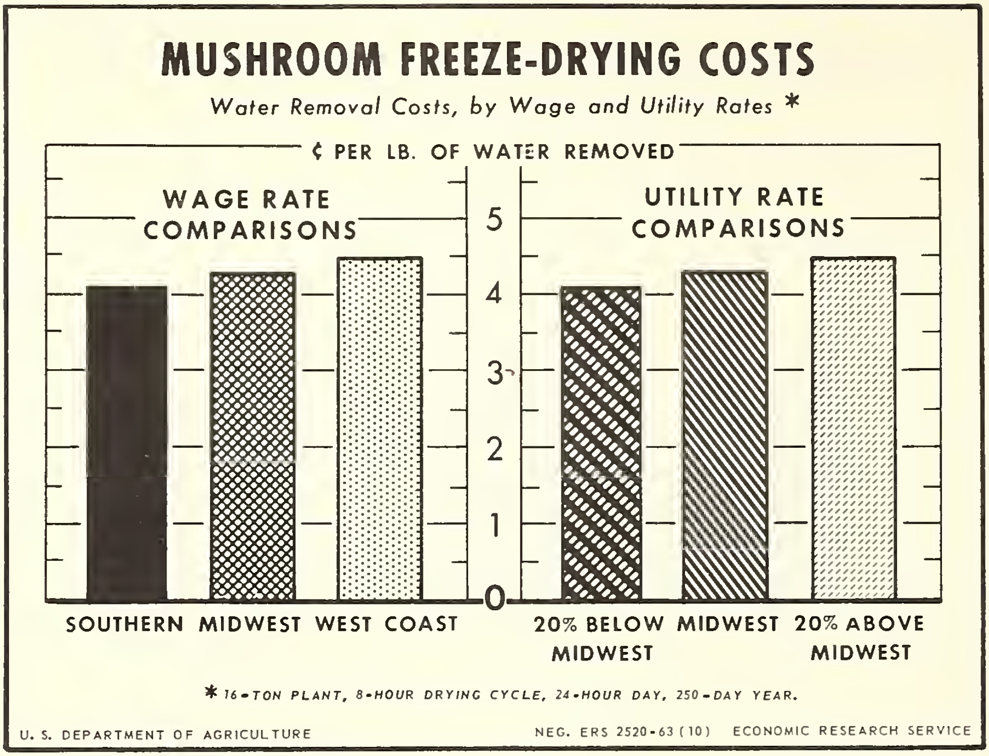

Figure 8

Utility rates vary throughout the country and there are no representative rates. In this analysis utility rates portray those prevailing in the Midwest. In some areas, particularly those served by the Niagara, Bonneville, and Tennessee Valley power complexes, electricity rates are lower. Steam rates may be as low as 50 cents per 1,000 pounds, or as high as $1.25. To show the effect of three utility rates we use the typical Midwest rates, those 20 percent below, and some 20 percent above (fig. 8). Average costs in areas where utility rates are 20 percent lower are 4.1 cents per pound of water removed compared with 4.3 cents in the Midwest. Areas with rates 20 percent above have processing costs of 4.5 cents. Since utility costs are about one-fifth of total costs, utility rates are important to consider when locating a new freeze-drying operation. Utility rate differentials have about the same effect on average costs as labor rate differences.

IMPLICATIONS OF COSTS

Based on our cost information, we expect future freeze-drying costs to reach a level of about 4 to 5 cents per pound of water removed. This would be equal to 6 to 8 cents per pound of frozen poultry or red meat. Or if shellfish were dried, costs would be about 6 to 7 cents per pound of incoming frozen product. High-moisture vegetables and fruits would have costs of about 5 cents per pound of frozen-weight equivalent. These are freeze-dry processing costs only, and do not include freezing, food preparation, or packaging.

Freeze-drying costs, as described here, are in addition to most canning or freezing costs. Thus, if we compare freeze-dry processing costs with canning or freezing costs, the extra costs of freeze-drying might reasonably be in the range of 4 to 8 cents per pound of product.

Before discussing anticipated growth of the freeze-drying industry, let us pose questions that may point out areas of relevance.

1. What foods might be processed by freeze-drying?

2. What are the competitive aspects between freeze-drying and other food processing industries?

3. Where might future freeze-drying plants be located?

4. What are likely markets for freeze-dried foods?

Foods That May be Freeze-Dried

Freeze-dry processing costs are high enough to place limits on the number and kind of foods handled. Since processing costs range from 4 to 8 cents per pound of food (frozen equivalent), costs reflected in prices would be considerably higher than this when products actually reach consumers. Offsetting factors are lower transportation and storage costs than for conventionally processed foods. These savings, however, are not as important as generally supposed.

It is apparent that many inexpensive calorie-supplying foods will not attain great freeze-drying volumes if 8 or more cents per pound are added to their retail prices. With this in mind, we eliminate from our list of potential freeze-dried foods a group of vegetables including potatoes, green beans, lima beans, carrots, beets, turnips, peas, sweet corn, and cabbage. By the same reasoning we also eliminate some lower-priced fruits such as apples, peaches, oranges, pineapples, and pears. However, many fruits and vegetables may be freeze-dried for special uses -- camping, remanufacture, and armed forces. Cheaper cuts of meat -- especially pork cuts, many beef cuts, and some poultry parts -- could not bear the additional freeze-dry processing costs. Many fishery products are of low economic value and thus not adaptable to freeze-drying.

In addition to costs, other factors limit the market for freeze-dried foods. Some products do not freeze-dry satisfactorily. In general, these include foods high in fat or sugar content.

Another group with limited applicability in freeze-drying includes foods that lose their physical characteristics when frozen, such as tomatoes, melons, and lettuce. If original form of the product is not important, some of these foods freeze-dry satisfactorily. Tomato puree and powder are examples.

Some classes of foods that appear promising as freeze-dried items include:

1. Meats. Since many meats are of high economic value, these will probably be freeze-dried in fairly large quantities. However, freeze-dried meats probably will not be used as substitutes for fresh or frozen meats. Rather, they will be used in dried mixes, camping packs, armed forces rations, and for other specialized uses. Primary among the meats are poultry and beef.

2. Seafoods. Shellfish and some other fish are of fairly high economic value per pound. They freeze-dry satisfactorily and probably will be freeze-dried in substantial quantities.

3. Specialized foods. This group includes instant coffee, instant tea, spices, seasonings, and extracts. Many are well adapted physically to freeze-drying. They are of high economic value and may not be limited by high processing costs. Since many will be used to mix with other dried foods to enhance flavor, processing costs are not so important.

4. Fruits. Many deciduous, tropical, and citrus fruits have the desired physical characteristics for freeze-drying. A number are of sufficient value to justify extra processing costs. An example is apple slices for cereals, pies, and other bakery products.

5. Berries. Almost all berries freeze-dry satisfactorily and are high enough in economic value for additional processing. They may be found in dry cereals, bakery products, prepared bake mixes, gelatin desserts, prepared puddings, and other items.

6. Vegetables. Minor vegetables, including several members of the cabbage family, asparagus, onions, and mushrooms, meet the physical specifications and are of sufficiently high economic value to justify additional processing costs. These may be used in stews, prepared casseroles, soups, prepared dinners, camper items, and others.

Competition of Freeze-Drying to Other Forms of Processing

What are the competitive aspects of freeze-drying to other food processing industries? Estimates are based largely upon costs of processing. First, if freeze-dry processing adds 4 to 8 cents per pound to the final product, we can judge whether it may be freeze-dried profitably instead of being frozen, canned, or heat-dried. Quality of most freeze-dried foods on the market is generally no better than comparably processed frozen or canned items. 10/ So, only when freeze-dried foods fill a specific need will they replace other items. This may be for armed forces use, camping, and uses where a dried food of good quality is desired. Since these needs are limited, we may expect little replacement of frozen and canned foods by freeze-dried items.

A more favorable comparison is between freeze-dried foods and heat-dried foods. The quality of foods now being heat-dried is unsatisfactory for many uses. Since freeze-dried foods are higher quality than most foods dried other ways, we may expect a substitution of freeze-dried for heat-dried products.

Location of Freeze-Drying Plants

The third question concerns possible locations of freeze-drying plants. This should be the subject of future studies, for it is complex. For our analysis, we assume that a freeze-drying operation will need to handle a large volume of product -- have a capacity of at least 40 tons of water per day and be employed throughout a

10/ For taste test comparisons of freeze-dried foods, see Bird, Kermit. Freeze-Dried Foods: Palatability Tests. U. S. Dept. Agr., Mktg. Res. Rpt. 617, Aug. 1963.

long season. We also assume the plant will be near the source of raw materials (frozen foods), rather than near the source of other inputs or the users of the food.

Likely locations of freeze-drying units are as follows: A meat drier would be near the center of the meat slaughtering industry, eastern Nebraska or western Iowa. California is important in fruit and vegetable processing and would be the site of several driers. The Pacific Northwest produces many fruits, vegetables, berries, and herbs. It has promise as a future location. The Eastern Seaboard area (Pennsylvania, Long Island, New Jersey, Delaware, and Maryland) is an important fruit and vegetable production area and also has well-developed mushroom and poultry industries. It appears promising. In addition, other areas in the Midwest, in the Lake States, and in the South appear to be likely choices.

Markets for Freeze-Dried Foods

One of the largest outlets for freeze-dried products is the armed forces. Many dried foods have been developed and tested by the Quartermaster Corps. These foods meet many of the unique requirements of the armed forces. Processing costs, although high, are not of prime importance. Foods expected to be used in large quantities include beef, chicken, turkey, several pork products including ham, shrimp, fish sticks and patties, several vegetables, several fruits, fruit and vegetable juices, instant cooked rice, chili and beans, and scrambled eggs. Items will be precooked for combat and emergency use, but uncooked for general mess usage.

Another large market expected for freeze-dried foods is remanufacturing. An example is chicken that is cooked, diced, frozen, freeze-dried, then mixed with other ingredients for use as chicken stew, chicken soup, chicken casserole, and other prepared dishes. In this market freeze-drying is an intermediate processing step.

A third market for freeze-dry products is the institutional one. It is "portion-control" and "convenience-food" conscious and since freeze-dried foods are packed without fat, bone, and other waste portions, they are adapted to this market. Many freeze-dried foods are cooked. They need no refrigeration. These attributes add to their desirability as convenience foods for particular segments of this market.

A fourth market is in specialized products, such as coffee, tea, seasonings, spices, and extracts. Such items may be used in remanufacturing, in institutions, or be retailed.

A fifth market is for camping. This small outlet shows signs of growing. Freeze-dried foods are well adapted. Freeze-dried camping items appeal to a small proportion of campers -- those not especially concerned about food costs, but desiring high-quality dried foods that rehydrate easily.

Finally, there is the retail grocery market. Several freeze-dried products are now retailed in soups or specialty items. High costs of processing will probably prevent most freeze-dried foods from being used in this market. Few freeze-dried foods are expected to attain large volumes in grocery stores.

Since freeze-drying costs are not expected to be low enough to be price competitive with canning or freezing, it is not anticipated that freeze-drying will radically alter present processing methods in the food industry. Exceptions might be in particular foods or items serving special uses. Nevertheless, the total products that may be freeze-dried are expected to reach substantial proportions in the future.

Projections for 1970

Estimates are made of volumes of freeze-dried foods in 1970, based upon anticipated uses. Since there are no accurate figures representing present or past production volumes, it is improbable that future freeze-drying projections would be highly accurate. We advise caution in their use. Anticipated volumes are based on processing cost estimates as presented here, results of taste tests, personal visits with officials of Military Subsistence of the Quartermaster Corps 11/, with economists of several major food processing companies, and editiors of food journals. These estimates are personal evaluations of the writer.

The general procedure in developing anticipated volumes was to list all food products appearing to have growth potential in freeze-drying. Then present or recent processed volume of each product was ascertained. Subjective estimates of the importance of freeze-drying relative to the total processed volume were made. 12/ These percentages of the total processing volume were used to derive estimated freeze-drying volumes.

Poultry is expected to be the largest meat item to be freeze-dried. In 1961, 2.9 billion pounds of poultry were canned and frozen in the United States. We estimate freeze-drying to be about 2 percent (a subjective figure) of this volume in 1970, or 58 million pounds. Processed red meat volume is now about 2.8 billion pounds, and our subjective estimate is about 1 per cent, 28 million pounds for 1970.

The next projected group is seafoods. Among shellfish, freeze-dried shrimp is most important. In 1962, 78 million pounds of shrimp were frozen and about 13 million were canned; total--91 million pounds. We estimate 10 percent of this volume to be freeze-dried by 1970, or 9 million pounds. Other shellfish may raise the total to about 10 million pounds. Fish other than shellfish are estimated at 5 million pounds. 13/

11/ Although Military Subsistence has temporarily laid aside plans to purchase freeze-dried foods for the combat meal, "Quick serve," it is contracting for fiscal year 1964 for the following quantities of freeze-dried food for regular mess rations: Beef steaks, flake, 76,000 lbs.; beef steaks, tenderized, 84,000 lbs.; beef patties 7,800 lbs.; pork chops 9,500 lbs.; and fish squares, 32,000. These amount to about 1 million pounds of fresh weight equivalent.

12/ In 1961 canned food processed in the United States (excluding seafoods, prepared mixes, and pet foods) totaled 19.3 billion pounds as follows: Fruits, including pineapple, 4.7 billion; juices, including pineapple, 2.8 billion; vegetables, 8.8 billion; poultry meats, 0.6 billion; and red meats, 2.4 billion.

In the same year, the volume of food frozen by commerical freezers in the United States (excluding seafoods, prepared meals, and dairy products) amounted to 6.7 billion pounds, as follows: Fruits and juices including concentrates, 1.7 billion; vegetables, 2.3 billion; poultry meats, 2.3 billion; and red meats, 0.4 billion pounds.

13/ Fishery estimates pertain to the 1962 catch. They were supplied by the Bureau of Commerical Fisheries, U. S. Department of Interior.

Canned fishery items (million pounds): Tuna, 344: salmon 182; sardines, East, 50; sardines, Pacific, 5; mackerel 54; crab, 8; shrimp, 14; clams, 9; diced, 15; oysters, 4; animal food, 374; other, 38; total 1,097 million pounds.

Frozen fishery items (million pounds): Shrimp, 78; other shellfish, 9; ocean perch, 26; haddock, 11; other, blocks, fillets, and steaks, 19; halibut, 43; whiting, 34; salmon, 15; other round and dressed, 45; bait and animal food, 63; total 343 million pounds.

Fruits, berries, and juices have a processed volume of about 9.2 billion pounds. If the freeze-dry market attains one-fourth of 1 percent of this, we expect freeze-dry volumes of these products at about 23 million pounds in 1970.

The volume of vegetables processed in this country totals about 11.1 billion pounds annually (1961). If one-eighth of 1 percent of this processed volume is freeze-dried, projected poundage of freeze-dried vegetables is 14 million for 1970.

The mushroom industry in this country had a total production of about 166 million pounds in 1961-62. Of this production about 52 percent of the mushrooms were canned and 15 percent were marketed as soup. The total processed volume was about 115 million pounds. If we anticipate that freeze-dried mushroom volumes equal about 7 percent of processed mushroom volumes, our estimate is 8 million pounds for 1970.

Freeze-dried dairy products are difficult to assess, since none are on the market. However, some are being tested and the armed forces have been contracting for several items. U.S. creamed cottage cheese production in 1962 was 782 million pounds. If the freeze-dry industry takes 1 percent, estimated production in 1970 is about 8 million pounds of freeze-dried cottage cheese. Cream cheese production in 1962 was 117 million pounds; 1 percent of this freeze-dried is about 1 million. Approximately 102 million pounds of sour cream are produced annually (1960 estimate); 1 percent of this is estimated as freeze-dried volume in 1970. Although precise figures for cheese dips are unavailable, market for freeze-drying is estimated at 1 million pounds in 1970. Freeze-dried dairy desserts are estimated at 2 million pounds. Other dairy products not listed may add 3 million pounds. Total freeze-dried dairy products in 1970 are estimated at 16 million pounds. 14/

Seasonings, flavorings, extracts, and similar products are estimated to reach a freeze-dried volume of 8 million pounds. Expected volume of instant beverages, including tea and coffee, is 20 million pounds. Gelatins, puddings, and desserts other than dairy desserts are 14 million pounds, although little volume data is available for use as reference guides.

Miscellaneous products to be freeze-dried, not included in those listed above, will be an estimated 15 million pounds. New products to be freeze-dried, those not now on the market, are anticipated at 25 million pounds.

The total estimated poundage of freeze-dried products in 1970 is summarized as follows:

	Mil. lbs.		Mil. lbs.
Poultry meats	58	Dairy products	16
Red meats	28	Seasonings	8
Shellfish	9	Beverages	20
Other fish	5	Desserts	14
Fruits, berries, juices	23	Miscellaneous items	15
Vegetables	14	New items not now marketed	25
Mushrooms	8	Total	243

14/ Statistical Reporting Service. Production of Manufactured Dairy Products. U. S. Dept. Agr. Stat. Rpt. Serv. DA 2-1 (63)

All figures are in fresh or frozen weight equivalents. If we place $1.00 per pound value (fresh weight equivalent) on these products, estimated value is $250 million.

If processing costs are 10 cents per pound of water removed, and we assume 200 million pounds of water are removed, the processing cost for the 243 million pounds is $20 million.

We estimate the number of freeze-drying plants needed to dry this 243 million pounds. If our hypothetical plants are operated 24 hours per day for 250 days per year, the industry would need about 12 plants the size of our 32-ton model. If the plants operate only 200 days per year, 16 would be needed. If 4-ton plants operating 200 days per year were used, 125 would be required.

Since the industry now has a capacity of about 10-12 million pounds of product per year, the estimated volume of 243 million pounds in 1970 is an increase of 20-fold. To reach these levels, the industry would have to increase its capacity each year by 50 percent for the next 7 years.

Beyond 1970, volume production is anticipated to continue growing at about the same rate. If the growth curve continues to 1975, the capacity of the industry will be 1.5 billion pounds of frozen input product. This would be 1 billion pounds of water removed and 1/2 billion pounds of dried foods.

APPENDIX

Assumptions

Pertinent restrictions limiting the analysis of the model freeze-drying plants are outlined.

Time: Several units of time are used. Fixed costs for time worked are constant and unchangeable on a yearly basis. Variable costs fluctuate daily with changes in daily output.

The short run is a time period in which model firms are unable to vary such fixed costs as salaries, interest, taxes, insurance, depreciation, and maintenance. The long run is a time period in which all costs may be varied. Each cost item is identified as either fixed or variable.

Geographic Location: Model plants are located in the Midwest. Costs affected by location are delivery and installation costs of freeze-drying equipment, utility rates, and wage rates. There are several instances where location is deliberately altered to show cost effects of labor and utilities.

Wage Rates: Wages pertain to money paid to hourly, not salaried, employees. Wage rates vary throughout the country. In this study Omaha, Nebr., wage levels are used. Wage rates are the same, for a given job, for all sizes of plants.

Salaries pertain to money paid to monthly employees, including manager, clerk, and secretary. Salaries vary among plants depending on the size of plant and responsibilities of the workers.

Fringe Benefits include Social Security, unemployment insurance, workmen's compensation, sick leave, and clothing allowance. A 14-percent rate is applied to all wages and salaries--direct and indirect. Annual vacation is not included as a fringe benefit; labor productivity standards and wage rates take this into consideration.

Management and Ownership: Each model plant is independently owned. Processing costs include a return to investment of 6 percent per annum. Profit is not included as a processing cost, but is a residual between cost and selling price. The manager of each model plant has full responsibility to make all management decisions. Product selling and procurement costs are not discussed.

Raw Products and Supplies include frozen products, cans, cartons, cases, and labels. They are not considered as processing costs. Neither are charges for labor in packing and packaging operations.

Batch Process: All freeze-drying in the model plants is done in cabinets. No flow-process equipment is used. This specification is realistic considering the present state of technical development of flow-process equipment. It is recognized, however, that flow equipment is being developed and soon will be used. Cycles are staggered to take advantage of power requirements and labor. All food is placed on trays and loaded according to the cycle length and product requirements.

Utilities include water, steam, nitrogen, electricity, sewerage, and heat and light. These are assumed available without capital expenditure. Rates charged are computed relative to costs as if utilities were furnished by equipment owned and operated by the firm. Rates are similar to those in Midwest locations.

Equipment Costs: The life of the freeze-drying equipment is 5 years, with 6,000 production hours per year and 24 hours per day. This equipment has a 30-percent salvage value. Thus, the annual rate for freeze-dry equipment is 14 percent. Maintenance costs of freeze-dry equipment are 0.5 percent of initial costs. Insurance and taxes are 3 percent. Interest is 3 percent of initial cost. Equipment other than that used for drying has similar costs, except depreciation is 10 percent rather than 14 percent of initial cost.

Labor Units: Labor charged to the freeze-drying process is available in man-hours, rather than in modules of 8-hour men. This is consistent with a drying operation that is part of a larger company in which labor is movable to and from the freeze-drying operation.

Supply Prices: The processing firm takes such a small proportion of the total amount of a given resource that is does not influence resource prices. The firm can get all it wants of any resource at quoted prices.

Physical Specifications of Equipment: Each model plant is designed, on paper, to provide the volume flow for each specified capacity. The equipment dries satisfactorily and produces foods of a suitable quality. Water removed is handled by a combination of mechanical pumps and steam jets. Condensers are tied together and have adequate ice-collecting and holding capacity. Drying-cycle temperatures are automatically controlled and correct for the products involved. Materials-handling, equipment cost estimates, investment requirements, and labor standards are provided.

Glossary

Following are some definitions of terms commonly used in this report.

Plant is a self-sufficient freeze-drying unit. It may be thought of as a single department of a larger, more complete processing operation. Other processing functions, related but not contained within the freeze-drying department, are food preparation, quick-freezing, warehousing, and packaging.

All labor, management, equipment, building, utilities, and other input factors are present or available in the approximately correct amounts necessary for each model plant to perform freeze-drying at specified levels.

Volume is a measure of flow per day or per year passing through the plant. Usually this flow is the amount of water removed from the raw product. It may be specified in terms of pounds of frozen or dried product.

Capacity or Scale is the maximum potential volume of output or throughput of the equipment and labor force, as delineated for the particular plant under consideration for the time and condition specified. It is not a maximum product flow. It is obtained with average employees working full time under normal conditions with prevailing wages and the specified equipment, 24 hours per day, 250 days per year.

Factors limiting capacity are cabinets and water removal equipment. For example, the 4-ton plant is limited in its water handling ability to 4 tons per 24-hour day. Volume cannot exceed this level. The 8-ton plant has a capacity of 8 tons of water per day. Capacity or scale has doubled, since water handling capacity has doubled. A plant adding a second labor shift does not change scale or capacity, even though output per day or per year may double.

Input and Output: Input is a production factor. It may be an hour of labor or use of a capital good, such as a machine or building, for a specified period. Output is a measure of achievement or work accomplished. It may be pounds of water extracted, pounds of dried product, or rehydrated-equivalent product.

Production Standard is a unit of time applied to a given job. It is an attainable time using good methods with efficient labor. Sometimes these standards are called input coefficients or labor requirements.

Short-run Cost Curves portray average costs of particular plants of a given size. Fixed production factors do not vary. Thus, these curves show that as a plant increases its volume flow, fixed costs are spread over more units of production. Average costs decline. During this stage, fixed production units are getting into better balance relative to variable units. As volume increases, more variable units are combined with fixed units. Eventually the plant would get out of balance in the other direction and marginal and average costs would increase.

Long-run Cost Curves are the same as economy-of-scale curves. As opposed to short-run curves, fixed factors are free to vary. The long-run curve shows the minimum level of costs that may be expected from various plants organized and operated as efficiently as possible. This curve, tangent to short-run curves, may be considered the minimum-cost curve for a number of plants of various sizes. It is used for long-range planning and shows least costs of prospective plants.

Cycle refers to length of drying period, including loading, unloading, and cleaning. Twelve-hour, 10-hour, and 8-hour cycles are examined.

Shift refers to the labor force working an 8-hour period. Split and overtime shifts are not used. Three shift arrangements are analyzed; 1,2, and 3 shifts per 24-hour day.

Cabinet consists of an airtight chamber or room with doors at each end for loading and unloading. Trays of food to be dried are placed between heating plates. Controlled inputs of heat are applied. Ducts lead out to water removal equipment. Each cabinet

contains 500 square feet of shelf area. Each cabinet has a door on each end, so the processed food is unloaded to a different work area.

Flushing refers to breaking the vacuum within a cabinet. In model plants this is done by inserting nitrogen gas so as to minimize product oxidation. The exception is in processing mushrooms, where air is used to break the vacuum.

Table 6.--The 4-ton model: Synthesized costs of freeze-drying four foods 1/

Item	Unit	Product being dried			
		Chicken	Beef	Shrimp	Mushrooms
Capacity per day:					
Water removed	Lb.	8,000	8,000	8,000	8,000
Frozen product (input)	Lb.	14,815	13,793	11,696	9,091
Dried product (output)	Lb.	6,815	5,793	3,696	1,091
Capacity per year:					
Water removed	Mil.lb.	2.0	2.0	2.0	2.0
Frozen product (input)	Mil.lb.	3.7	3.4	2.9	2.3
Dried product (output)	Mil.lb.	1.7	1.4	0.9	0.3
Product per square ft. of shelf area	Lb.	2.5	2.5	2.5	2.0
Shelf area needed	Sq. ft.	1,975	1,839	1,559	1,515
Investment in freeze-dry equipment @ $150 per sq. ft. shelf area	Dol.	300,000	300,000	300,000	225,000
Fixed expenses:					
Annual freeze-dry equipment expenses: Depreciation 14%, insurance and taxes 2½%, interest 3%, maintenance 1%	Dol.	61,500	61,500	61,500	46,125
Annual costs of other equipment	Dol.	824	824	824	824
Annual building cost	Dol.	4,406	4,406	4,406	4,406
Office rental	Dol.	420	420	420	420
Telephone and telegraph	Dol.	600	600	600	600
Management salaries and fringe benefits	Dol.	6,840	6,840	6,840	6,840
Total annual fixed expenses	Dol.	74,590	74,590	74,590	59,215
Variable expenses:					
Direct and indirect labor and fringe benefits per day	Dol.	198.88	196.97	191.22	183.56
Maintenance and repairs per day	Dol.	6.09	6.09	6.09	4.59
Utilities per day	Dol.	134.76	134.76	134.76	102.76
Total variable costs per day	Dol.	339.73	337.82	332.07	290.91
Processing costs per year	Dol.	159,523	157,045	157,608	131,943
Processing cost per pound of water removed	Cent	8.0	7.9	7.9	6.6
Processing cost per pound of frozen food	Cent	4.3	4.6	5.4	5.8
Processing cost per pound of dried food	Cent	9.4	10.8	17.1	48.4

1/ Plant operates 24 hours per day, 250 days per year, and uses 8-hour drying cycles. Input product is frozen; dried product has 2 percent moisture. Midwest wages and utility rates apply.

Table 7.--The 8-ton model: Synthesized costs of freeze-drying four foods 1/

Item	Unit	Product being dried			
		Chicken	Beef	Shrimp	Mushrooms
Capacity per day:					
Water removed	Lb.	16,000	16,000	16,000	16,000
Frozen product (input)	Lb.	29,630	27,586	23,392	18,182
Dried product (output)	Lb.	13,630	11,586	7,392	2,182
Capacity per year:					
Water removed	Mil.lb.	4.0	4.0	4.0	4.0
Frozen product (input)	Mil.lb.	7.4	6.9	5.8	4.5
Dried product (output)	Mil.lb.	3.4	2.9	1.8	0.5
Product per square foot of shelf area	Lb.	2.5	2.5	2.5	2.0
Shelf area needed	Sq.ft.	3,951	3,678	3,119	3,030
Investment in freeze-dry equipment @ $145 per sq. ft. of shelf area	Dol.	580,000	580,000	507,500	435,000
Annual freeze-dry equipment expenses: Depreciation 14%, insurance and taxes 2½%, interest 3%, maintenance 1%	Dol.	118,900	118,900	104,038	89,175
Annual cost of other equipment	Dol.	1,116	1,116	1,116	1,116
Annual building cost	Dol.	7,436	7,436	7,436	7,436
Office rental	Dol.	504	504	504	504
Telephone and telegraph	Dol.	750	750	750	750
Management salaries and fringe benefits	Dol.	9,291	9,291	9,291	9,291
Total annual fixed expenses	Dol.	137,997	139,997	123,135	108,272
Variable expenses:					
Direct and indirect labor and fringe benefits per day	Dol.	263.56	259.73	250.15	231.00
Maintenance and repairs	Dol.	11.72	11.72	10.27	8.82
Utilities per day	Dol.	237.11	237.11	230.11	181.11
Total variable costs per day	Dol.	512.39	508.56	490.53	420.93
Processing cost per year	Dol.	266,094	267,137	245,767	213,504
Processing cost per pound of water removed	Cent	6.7	6.6	6.1	5.3
Processing cost per pound of frozen food	Cent	3.6	3.9	4.2	4.7
Processing cost per pound of dried food	Cent	7.8	9.2	13.7	42.7

1/ Plant operates 24 hours per day, 250 days per year, and uses 8-hour drying cycles. Input product is frozen; dried product has 2 percent moisture. Midwest wages and utility rates apply.

Table 8.--The 16-ton model: Synthesized costs of freeze-drying four foods 1/

Item	Unit	Plant being dried			
		Chicken	Beef	Shrimp	Mushrooms
Capacity per day:					
Water removed	Lb.	32,000	32,000	32,000	32,000
Frozen product (input)	Lb.	59,259	55,172	46,784	36,364
Dried product (output)	Lb.	27,259	23,172	14,784	4,364
Capacity per year:					
Water removed	Mil.lb.	8.0	8.0	8.0	8.0
Frozen product (input)	Mil.lb.	14.8	13.8	11.7	9.1
Dried product (output)	Mil.lb.	6.8	5.8	3.7	1.1
Product per square foot of shelf area	Mil.lb.	2.5	2.5	2.5	2.0
Shelf area needed	Sq. ft.	7,901	7,356	6,238	6,061
Investment in freeze-dry equipment @ $130 per sq. ft. shelf area	Dol.	1,040,000	975,000	845,000	780,000
Fixed expenses:					
Annual freeze-dry equipment expenses: Depreciation 14%, insurance and taxes 2½%, interest 3%, maintenance 1%	Dol.	213,200	199,875	173,225	159,900
Annual costs of other equipment	Dol.	1,422	1,422	1,422	1,422
Annual building cost	Dol.	13,657	13,657	13,657	13,657
Office rental	Dol.	588	588	588	588
Telephone and telegraph	Dol.	900	900	900	900
Management salaries and fringe benefits	Dol.	12,312	12,312	12,312	12,312
Total annual fixed costs	Dol.	242,079	228,754	202,104	188,779
Variable expenses:					
Direct and indirect labor and fringe benefits per day	Dol.	324.57	320.74	307.33	288.18
Maintenance and repairs per day	Dol.	20.96	19.66	17.06	17.06
Utilities per day	Dol.	411.00	405.00	393.00	315.00
Total variable costs per day	Dol.	756.53	745.40	717.39	620.24
Processing costs per year	Dol.	431,212	415,104	381,452	343,839
Processing cost per pound of water removed	Cent	5.4	5.2	4.8	4.3
Processing cost per pound of frozen food	Cent	2.9	3.0	3.3	3.8
Processing cost per pound of dried food	Cent	6.3	7.2	10.3	31.3

1/ Plant operates 24 hours per day, 250 days per year, and uses 8-hour drying cycles. Input product is frozen; dried product has 2 percent moisture. Midwest wages and utility rates apply.

Table 9.--The 32-ton model: Synthesized costs of freeze-drying four foods 1/

Item	Unit	Chicken	Beef	Shrimp	Mushrooms
Capacity per day:					
Water removed	Lb.	64,000	64,000	64,000	64,000
Frozen product (input)	Lb.	118,518	110,345	93,567	72,727
Dried product (output)	Lb.	54,518	46,345	29,567	8,727
Capacity per year:					
Water removed	Mil.lb.	16.0	16.0	16.0	16.0
Frozen product (input)	Mil.lb.	29.6	27.6	23.4	18.2
Dried product (output)	Mil.lb.	13.6	11.6	7.4	2.2
Product per square foot of shelf area	Mil.lb.	2.5	2.5	2.5	2.0
Shelf area needed	Sq. ft.	15,802	14,713	12,476	12,121
Investment in freeze-dry equipment @ $115 per sq. ft. shelf area	Mil.dol.	1.840	1.725	1.438	1.438
Fixed expenses:					
Annual freeze-dry equipment expenses Depreciation 14%, insurance and taxes 2½%, interest 3%, maintenance 1%	Dol.	377,200	353,625	294,688	294,688
Annual costs of other equipment	Dol.	1,620	1,620	1,620	1,620
Annual building cost	Dol.	23,735	23,735	23,735	23,735
Office rental	Dol.	700	700	700	700
Telephone and telegraph	Dol.	1,000	1,000	1,000	1,000
Management salaries and fringe benefits	Dol.	18,012	18,012	18,012	18,012
Total annual fixed expenses	Dol.	422,267	398,692	339,755	339,755
Variable expenses:					
Direct and indirect labor and fringe benefits per day	Dol.	383.90	378.15	360.91	334.10
Maintenance and repairs per day	Dol.	36.98	34.68	28.93	28.93
Utilities per day	Dol.	733.54	723.54	698.54	573.54
Total variable costs per day	Dol.	1,154.42	1,136.37	1,088.38	936.57
Processing costs per year	Dol.	710,872	632,784	611,850	573,897
Processing costs per year	Cent	4.4	4.3	3.8	3.6
Processing cost per pound of frozen food	Cent	2.4	2.5	2.6	3.2
Processing cost per pound of dried food	Cent	5.2	5.9	8.3	26.1

1/ Plant operates 24 hours per day, 250 days per year, and uses 8-hour drying cycles. Input product is frozen; dried product has 2 percent moisture. Midwest wages and utility rates apply.